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STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

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During this research period we have pursued research in different areas related to a better specification of the ionosphere. At high latitudes we have improved and expanded our model of the ionospheric convection pattern to include a plasma packet tracing algorithm. For specified IMF inputs this algorithm allows the user to specify a high latitude location as input and then computes the location to which a plasma packet at that location would move in some specified time. Such algorithms are now used in ionospheric specification codes to examine the formation of large scale plasma structures.

At middle latitudes, the appearance of ionization layers in the bottomside F-region has long been a subject of study. Such layers may have global electrodynamic consequences but equally important are questions concerning their composition. We will report on initial calculations to suggest that such layers may be formed entirely from local molecular species.

Finally, in the low and mid-latitude topside ionosphere we have started an extensive study of the ionospheric density and composition. Such a study is made possible by a new capability of the DMSP instrumentation and is relevant to the interpretation of TEC measurements

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Introduction.

During this research period we have pursued research in different areas related to a better specification of the ionosphere. At high latitudes we have improved and expanded our model of the ionospheric convection pattern [Hairston and Heelis,1990] to include a plasma packet tracing algorithm. For specified IMF inputs this algorithm allows the user to specify a high latitude location as input and then computes the location to which a plasma packet at that location would move in some specified time. Such algorithms are now used in ionospheric specification codes to examine the formation of large scale plasma structures.

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1. High Latitude Ionospheric Plasma Modeling

The appearance of plasma density enhancements in the polar cap are important because the represent the seat of irregularities that produce radio scintillations. The problem we wish to address is the mechanism that can produce such patches. It has been suggested that the high density plasma that constitutes a patch originates from the extremes of the plasmasphere and is convected through the cusp and structured by a temporally varying convection pattern. By using the previously developed plasma packet tracing algorithms we are able to test this hypothesis.

We have seen that time independent convection can lead to tongues of ionization bringing large ion densities into the polar cap. In an attempt to simulate structured enhanced plasma density observed over the Sondrestrom radar calculations including time dependent convection were performed. The measured and modeled critical frequencies are shown in Figure 1. There are clearly many small scale variations that cannot be easily reproduced by simple time variations in the convection. However major large scale features are reproduced

by modeling the changes in the convection pattern expected from changes in the prevailing IMF conditions. While this experiment addresses only one dimension of the so-called ionization patch it is encouraging that such patches could result in differing plasma convection profiles for neighboring regions.

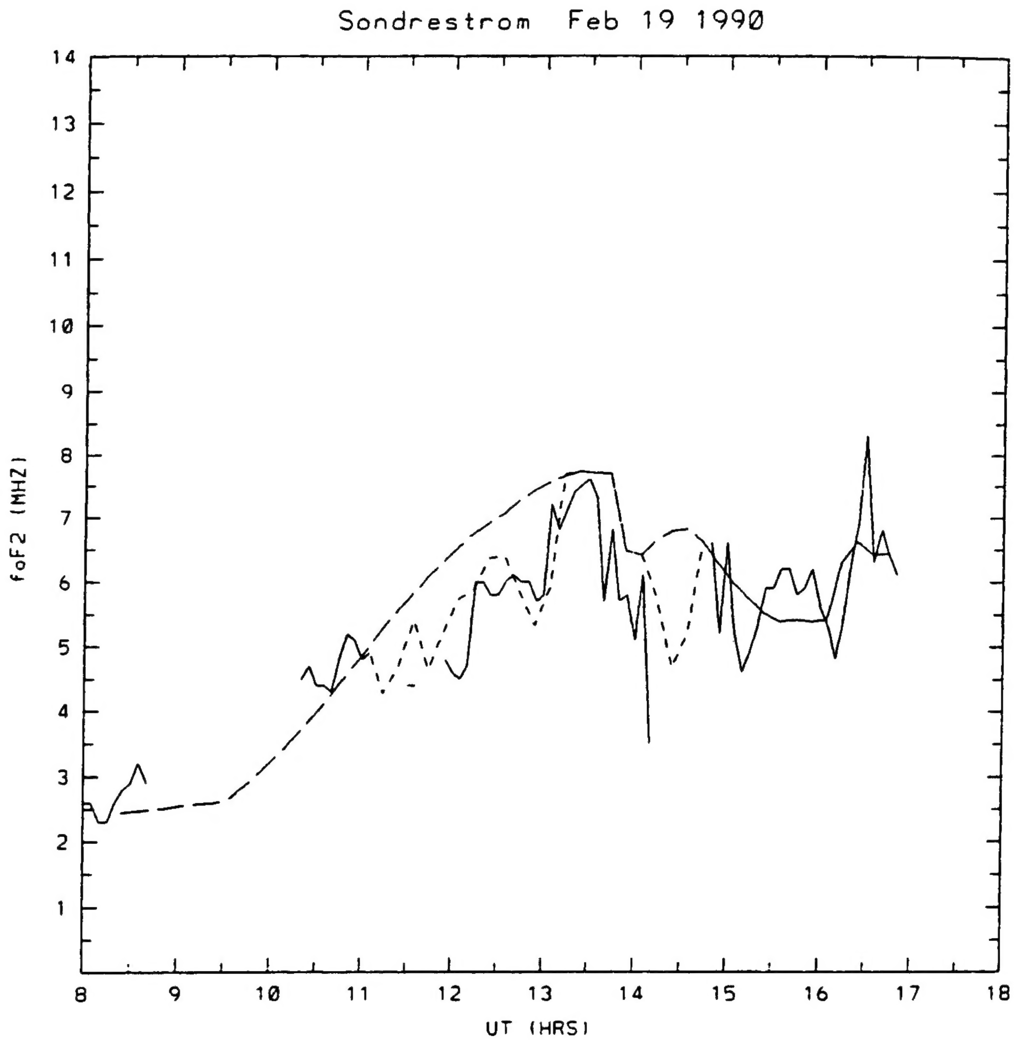

Figure 1. Measured and modeled F-region critical frequencies in the polar cap

2. Formation of Intermediate Layers

In this work we examined the effectiveness of meridional neutral winds in the production of intermediate layers from the ambient molecular ion background. Our approach is to apply different altitude profiles for the meridional wind on a flux tube approximating the ionosphere over Arecibo observatory. Sinusoidal profiles were chosen for the ease with which changing vertical wavelength and changing amplitude can be examined. Such winds

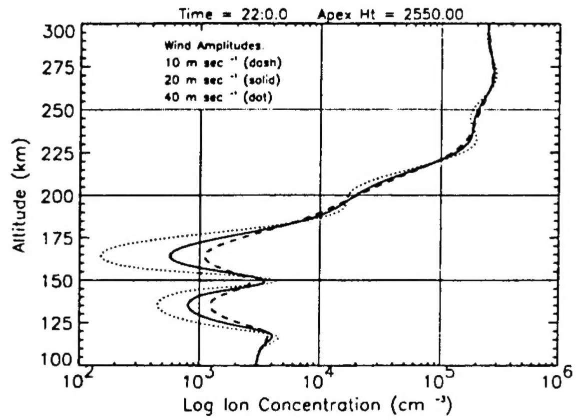

Figure 2. Layer formation for different amplitude meridional wind profiles

produce regions alternating in altitude where the plasma moves upward and downwards along the magnetic field. The drifts change with altitude dependent on the ion-neutral collision frequency and the resulting divergence in the field-aligned drifts produce regions of enhancement and depletion. In the altitude region between 200 and 400 km the increased background ionization of the nighttime F-region prevents the wind from forming a true layer despite the fact that the plasma is moved by the neutral wind. Below approximately 120 km altitude the large value of the ion-neutral collision frequency will prevent the formation of layers by meridional winds. Thus meridional winds are effective in the region between 120 km and 190 km. In this altitude region a layer may be rapidly formed by neutral winds of 10-30 ms-1 with vertical wavelengths of 20 - 40 km. The layers form in equilibrium after only 20 minutes or so. In equilibrium, chemical loss and diffusion are balanced by wind induced transport. Figure 2 shows layers produced by a stationary wind system with differing amplitude. It is important to note that the wind is effective in enhancing the density a little at the layer peak but more effectively it depletes the density in regions above and below the layer. Using the depleted density levels to determine the background ionization rate would lead to the conclusion that the layer peak densities cannot be maintained against chemical losses. However, the true background density may be much higher and as these results show maintenance of molecular ion layers by a meridional wind is easily achieved.

3. Topside Ionospheric Density and Composition

Measurements of topside ion composition from the DMSP satellite represents a significant opportunity to improve our understanding of the dynamics of this region. Here we describe the initial results from an investigation of the DMSP data. Figure 3 shows examples of the ion composition observed during dawn and dusk passes across the equator.

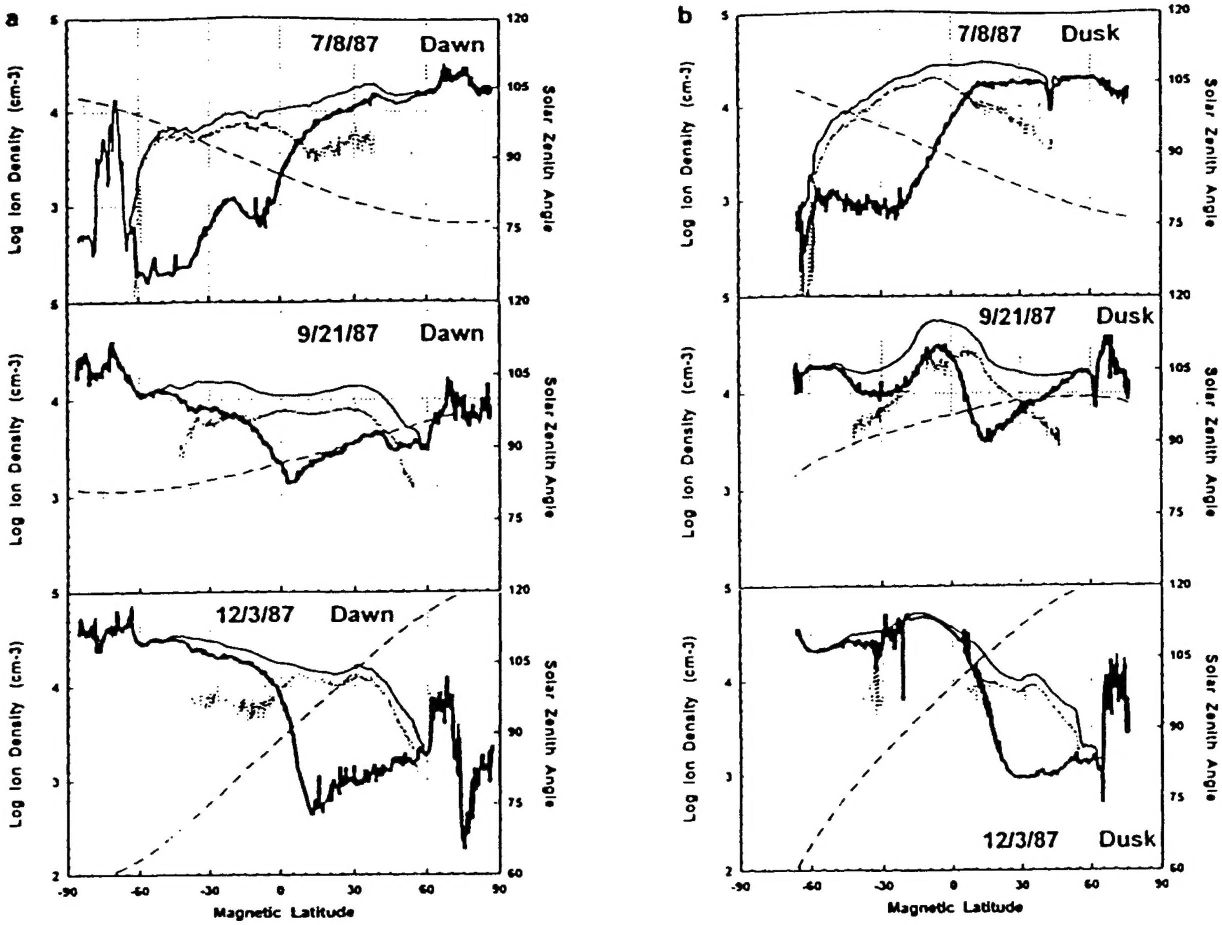

Figure 3. Latitude profiles of ionospheric composition during dawn and dusk passes of DMSP across the equator.

Light ions usually predominate at 840 km above the dark, winter ionosphere. During any given season we found remarkable day to day consistency in the observations. Clear variations with longitude and magnetic activity are evident and quite often the transition from light ions to the heavier O+ occurred below the satellite altitude. This is consistent with expectations based on previous observations and model calculations for the solar minimum conditions that prevail for the data set examined. Field-aligned transport driven by a combination of pressure gradients, ExB drifts and F-region neutral winds may qualitatively explain the longitude variations. During the daytime, upward transport is produced by photoionization below the spacecraft. At night, downward transport is produced by the recombination loss of ions below the spacecraft. These motions are modulated by ExB drifts and wind induced changes in the F-peak. There is also a suggestion that the ExB drift must depend on longitude as well.

References

Hairston, M. R., and R. A. Heelis, A model of the ionospheric convection pattern for southward IMF based on DE-2 observations, *J.Geophys. Res.*, **95**, 2333-2343, 1990.

Publications

The work described above has been systematically published in the leading journals in our field. Titles and abstracts of this published work are given below.

Modeling daytime *F* layer patches over Sondrestrom

D. T. Decker, C. E. Valladares, R. Sheehan,[1] Su. Basu,[1,2] D. N. Anderson,[3] and R. A. Heelis[4]

Abstract. A comprehensive, time-dependent, high-latitude, one-species *F* region model has been developed to study the various physical processes which are believed to affect the polar cap plasma density distributions as a function of altitude, latitude, longitude, and local time. These processes include production of ionization by solar extreme ultraviolet radiation and particle precipitation; loss through charge exchange with N_2 and O_2; and transport by diffusion, neutral winds, and convection $\mathbf{E} \times \mathbf{B}$ drifts. In our initial calculations we have modeled highly structured plasma densities characterized by digisonde observations at Sondrestrom using both a time-dependent global convection pattern and spatially localized regions of transient high-speed flow. We find that the model is very sensitive to the details of the time-dependent convection pattern, and both the time dependence and the high-speed flows contribute to the *F*-region structure. Further, when we use high-speed flows based on specific radar observations the simulated density structure is in reasonable agreement with that day's digisonde observations.

Modeling the formation of intermediate layers at Arecibo latitudes

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Abstract. By using a modified version of the ionospheric model described by Bailey and Sellek (1990), we model the formation of intermediate ionization layers due to meridional neutral winds in the valley region between the E and F regions. The calculations are performed on a single field line with $L = 1.4$, in order to compare the results with observations of intermediate layers from the incoherent scatter radar at Arecibo. The winds are given a sinusoidal variation in altitude, and the effects of the wind amplitude and wavelength on layer formation are examined. Nighttime ionization rates are artificially specified to correspond with observed rates in the region. Our results show that tidal like meridional wind profiles act to deplete the apparent background ionospheric number density as well as enhance the number density in the intermediate layer. Thus the layer appears as an enhancement above a background that is much smaller than the background that would be present in the absence of a wind. In this way, layers with relatively high molecular ion concentrations can exist. Intermediate layers are seen to form at nulls in the neutral wind altitude profile, but in the altitude region above roughly 160 km this null need not coincide with a zero in the field-aligned ion velocity.

DMSP F8 observations of the mid-latitude and low-latitude topside ionosphere near solar minimum

M. E. Greenspan,[1,2] W. J. Burke,[3] F. J. Rich,[3] W. J. Hughes,[1] and R. A. Heelis[4]

The retarding potential analyzer on the DMSP F8 satellite measured ion density, composition, temperature, and ram flow velocity at 840-km altitude near the dawn and dusk meridians close to solar minimum. Nine days of data were selected for study to represent the summer and winter solstices and the autumnal equinox under quiet, moderately active, and disturbed geomagnetic conditions. The observations revealed extensive regions of light-ion dominance along both the dawn and dusk legs of the DMSP F8 orbit. These regions showed seasonal, longitudinal, and geomagnetic control, with light ions commonly predominating in places where the subsatellite ionosphere was relatively cold. Field-aligned plasma flows also were detected. In the morning, ions flowed toward the equator from both sides. In the evening, DMSP F8 detected flows that either diverged away from the equator or were directed toward the northern hemisphere. The effects of diurnal variations in plasma pressure gradients in the ionosphere and plasmasphere, momentum coupling between neutral winds and ions at the feet of field lines, and E × B drifts qualitatively explain most features of these composition and velocity measurements.